Space Weather Technical Forecast

Issued on Thursday 2 January 2025 at 01:06 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: M-class flares expected, slight chance X-class flares. Chance G1 Minor Storms day 3 (04 Jan) from glancing CME and fast winds from a coronal hole.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Moderate with four M-class flares observed, peaking M1.2 at 01/1817 UTC from AR3936 on the northwest limb. This is the most active of the thirteen sunspot regions on the disc, with occasional M-class flares, but is now impossible to analyse due to its location. Significant growth was observed in a number of regions, including a new region in the southwest, along with AR3945 and AR3944 in the southeast, however these remain relatively simple with their magnetic structure. AR3939, in the southwest, is perhaps the most complex of the other regions on the disc, but remains relatively small with no significant flaring in the last 24 hours. Some notable magnetic looping is also evident on the northeast limb, which may suggest a further region to move onto the disc.

A weak filament eruption was observed from near AR3939 at 01/0130 and has been assessed as potentially giving a glancing impact on day 3 (04 Jan). The other observed CMEs are off the Earth-Sun line.

Solar Wind / Geomagnetic Activity: Ongoing CME influence at first, was followed by the arrival of a second CME enhancement, potentially around 01/0320 UTC, and a strong magnetic cloud. Solar winds increased from slightly elevated, 450km/s at 01/0320 UTC to be elevated at 500-550 km/s by 01/0600 UTC, and then persisted largely at this level. Density also increased slightly, at this time, and persisted above average (25-50 ppccm) until around 01/1400 UTC, before easing to average. Total Interplanetary Magnetic Field (IMF), Bt, was Moderate-to Strong until 01/1830 UTC, and persistently Strong at 21-26nT between 01/0900-01/1715 UTC. IMF then eased to be weak at 7nT by midnight. The north-south component, Bz, was generally weak to moderate negative (southward) at first, with brief positive (northward) spells, peak 12nT, but became persistently strongly negative at between 01/1030-1620 UTC, with minimum -23nT. Phi angle rotated from positive (away from the Sun) to negative (towards the Sun) but became largely neutral from 01/0900 UTC. Geomagnetic activity was Active to G2 Moderate Storm, with one G4 Severe Storm interval reported by BGS at 01/1500-1800 UTC. However other centres (Potsdam, SWPC) have reported G3 Strong Storm intervals for 01/1200-1500 and 011800-2100 UTC.

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Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV) at GOES18 remained background. High energy electron flux (greater than 2MeV) at GOES16 was at Background with the associated 24 hr fluence well below Active. The 02/0000 UTC fluence observation was 1.13e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Moderate activity is expected to continue with occasional M-class flares. There remains a slight chance of isolated X-class flares. This is despite the main active sunspot region AR3936 soon rotating off the visible disc, due to some sunspot growth observed, and further regions potentially rotating onto it.

Solar Wind / Geomagnetic Activity: There is one potential Earth-glancing CME, from a filament eruption near AR3939 early on 01 Jan, likely passing Earth on day 3 (04 Jan). However this is low confidence. Solar winds are currently elevated, but likely to ease as recent CME enhancements continue to wane. The next enhancement is likely to be from the onset of fast winds from CH05, the larger and northern of the two coronal holes on the disc, also on day 3 (04 Jan). Mainly Quiet to Unsettled geomagnetic activity is expected at first, with a slight chance of Active intervals from any ongoing CME influence. CH05 fast winds, and the CME arrival are likely to increase activity to Active to G1 Minor Storm on day 3, easing day 4 (04-05 Jan).

Energetic Particles / Solar Radiation: GOES18 high energy proton flux is expected to continue at background, but with a chance of an enhancement given any notable flares, especially those from the western disc, or just beyond the west limb. GOES16 high energy electron flux is expected to increase in response to the recent CME arrivals, potentially giving a spell of Moderate to High flux, before any further solar wind enhancement suppresses this. A further enhancement is then possible by the end of the period. The associated fluence is expected to remain below Active, with only a slight chance of rising above.

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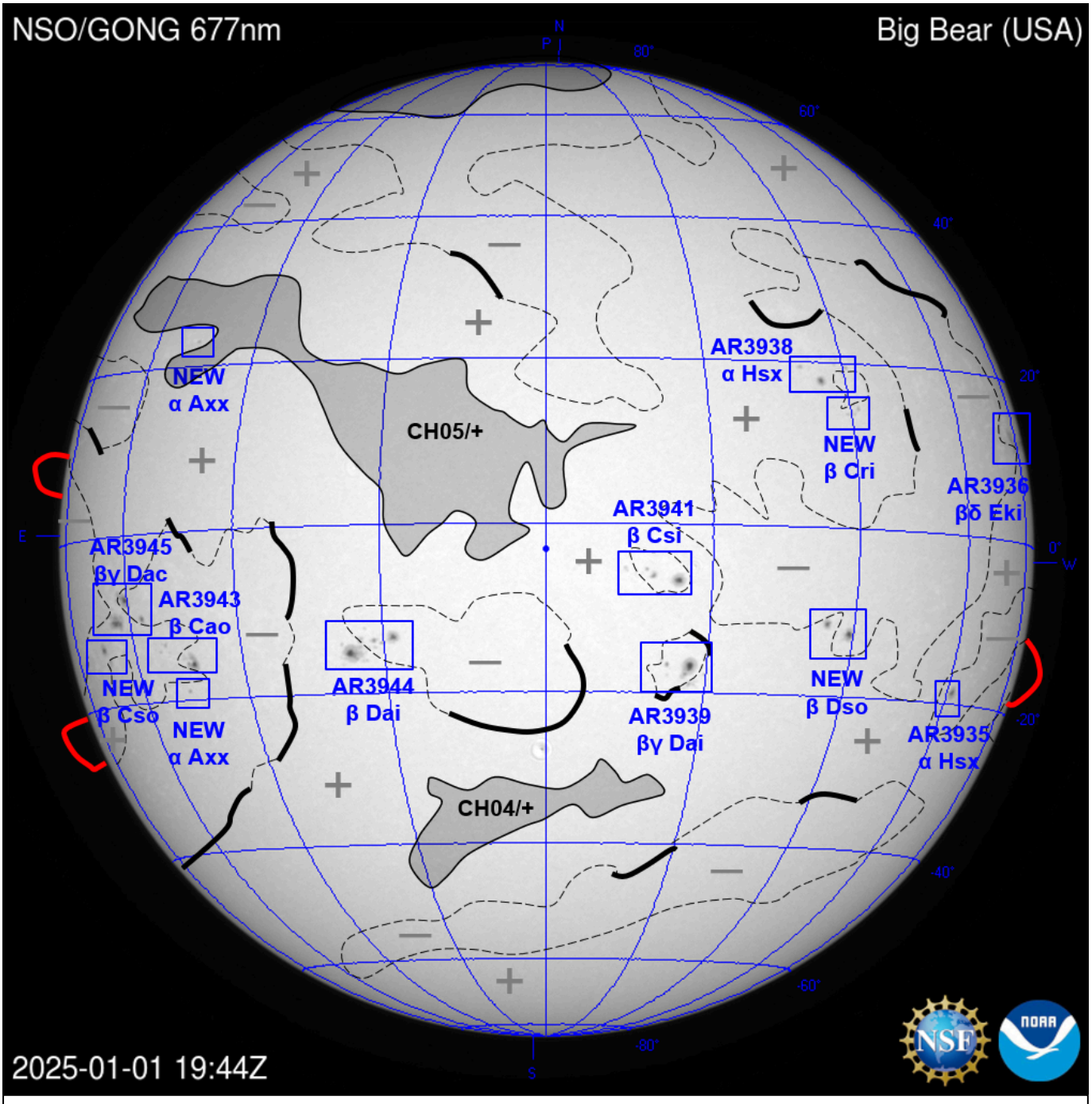
Figure 1: MOSWOC Solar Synoptic Map 01/2000 UTC



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Figure 2: BGS estimated geomagnetic activity.

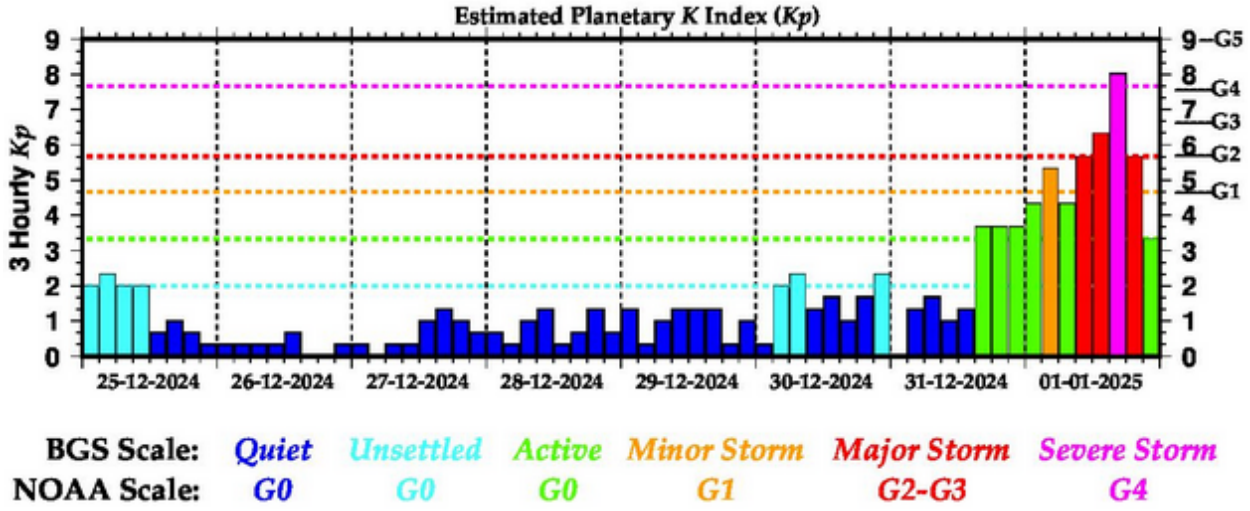
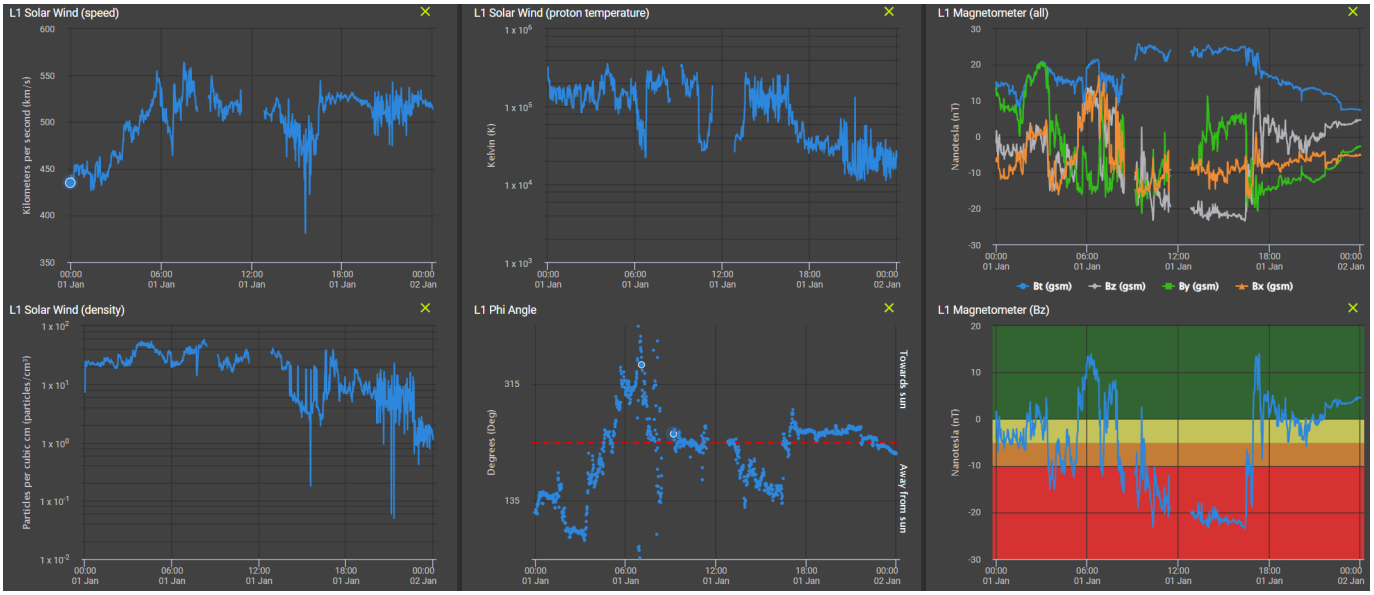


Figure 3: L1 Observed Solar winds, with strong magnetic cloud evident.



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Geomagnetic Storms

There is one potential Earth-glancing CME, from a weak filament eruption early on 01 Jan from the vicinity of AR3939. This is expected to pass Earth early on day 3 (04 Jan).

Solar winds are currently elevated, easing from the CME arrivals on 31 Dec and 01 Jan, with geomagnetic activity initially Quiet to Unsettled, with only a slight chance of isolated Active intervals day 1-2 (02-03 Jan).

The other main features in the forecast are the large positive coronal holes CH04 in the south, and CH05 in the north. These have a similar leading edge, currently around 10-15W. The most likely of these to influence Earth is the northern CH05, as CH04 is likely too far south to have an impact. CH05 was smaller and further east on the previous rotation, and was observed on the equivalent of day 4 (05 Jan), with solar winds of around 500 km/s. Enlil however, indicates a weak connection to the very southern edge of the features fast wind on day 3 (04 Jan). Given the current location and the potential for the feature to be stronger than last rotation, due to its persistence, then this potential arrival time is currently accepted.

Any CME arrival could occur alongside the coronal hole enhancement, so despite it not being the most favourable time of year for a strong connection to this feature, this will still bring a potential for Active to G1 Minor Storms on day 3 (04 Jan). There is a slight chance of G2 Moderate storm intervals. Elevated solar winds are expected to continue day 4 (05 Jan) with Unsettled to Active geomagnetic activity and a slight chance of G1 Minor Storm intervals.

Geomagnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	**G1 to G2**	Yes	5	5	40	20
Strong	**G3**	Yes	1	1	1	1
Severe	**G4**	Yes	1	1	1	1
Extreme	**G5**	No	1	1	1	1

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Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R⊙ (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed (km/s)	Estimated Arrival Time (UTC)	Comments
01/0740	Partial	Filament	South-centre	560	04/0300 UTC (+/- 9hrs)	Filament eruption nr. AR3939. Low confidence, glancing impact.

Figure 4: GOES SUVI of current rotation (left) and previous (right). Both CH's larger and further west, most notable on the northern CH05

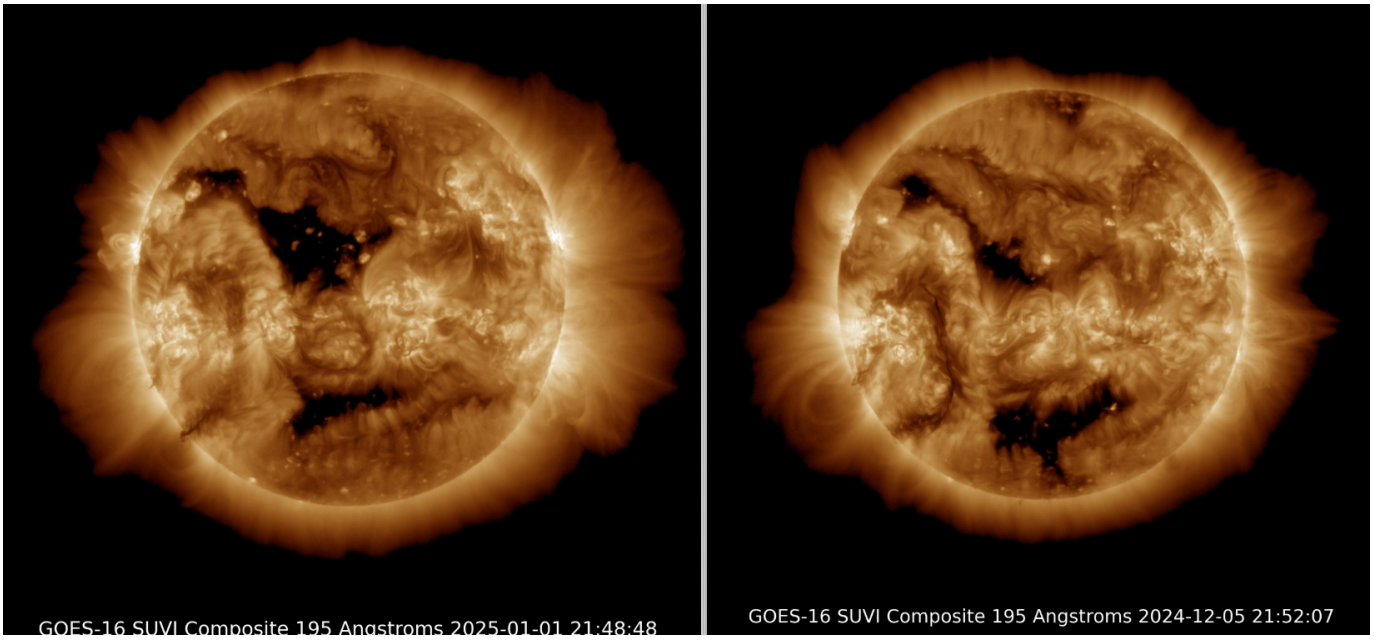

Figure 5: MOSWOC Solar Wind Persistence Model. Early enhancement likely on this rotation.

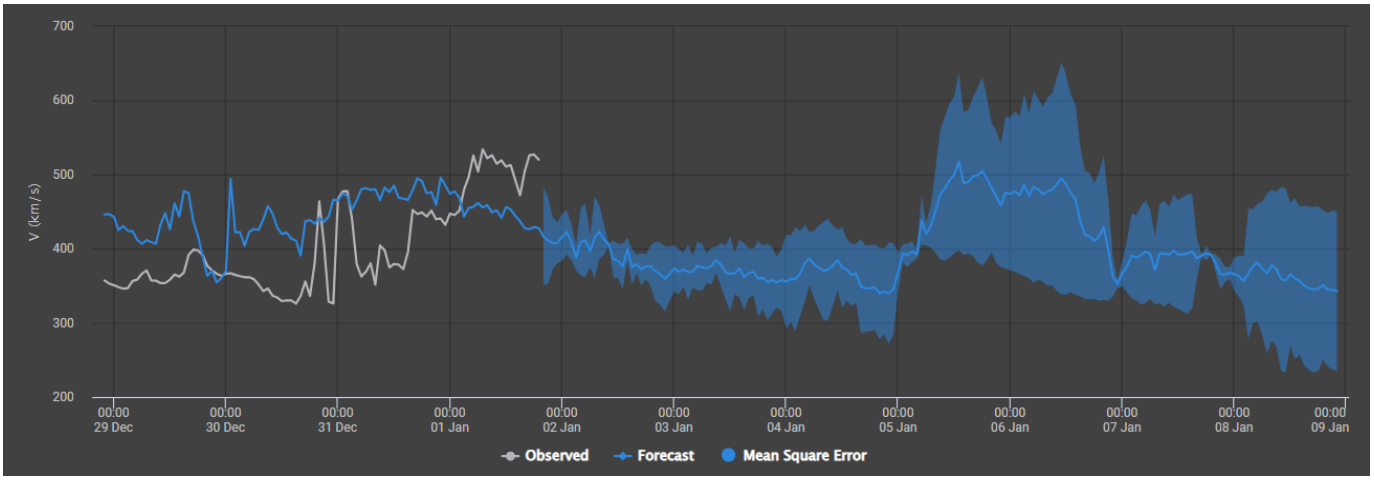

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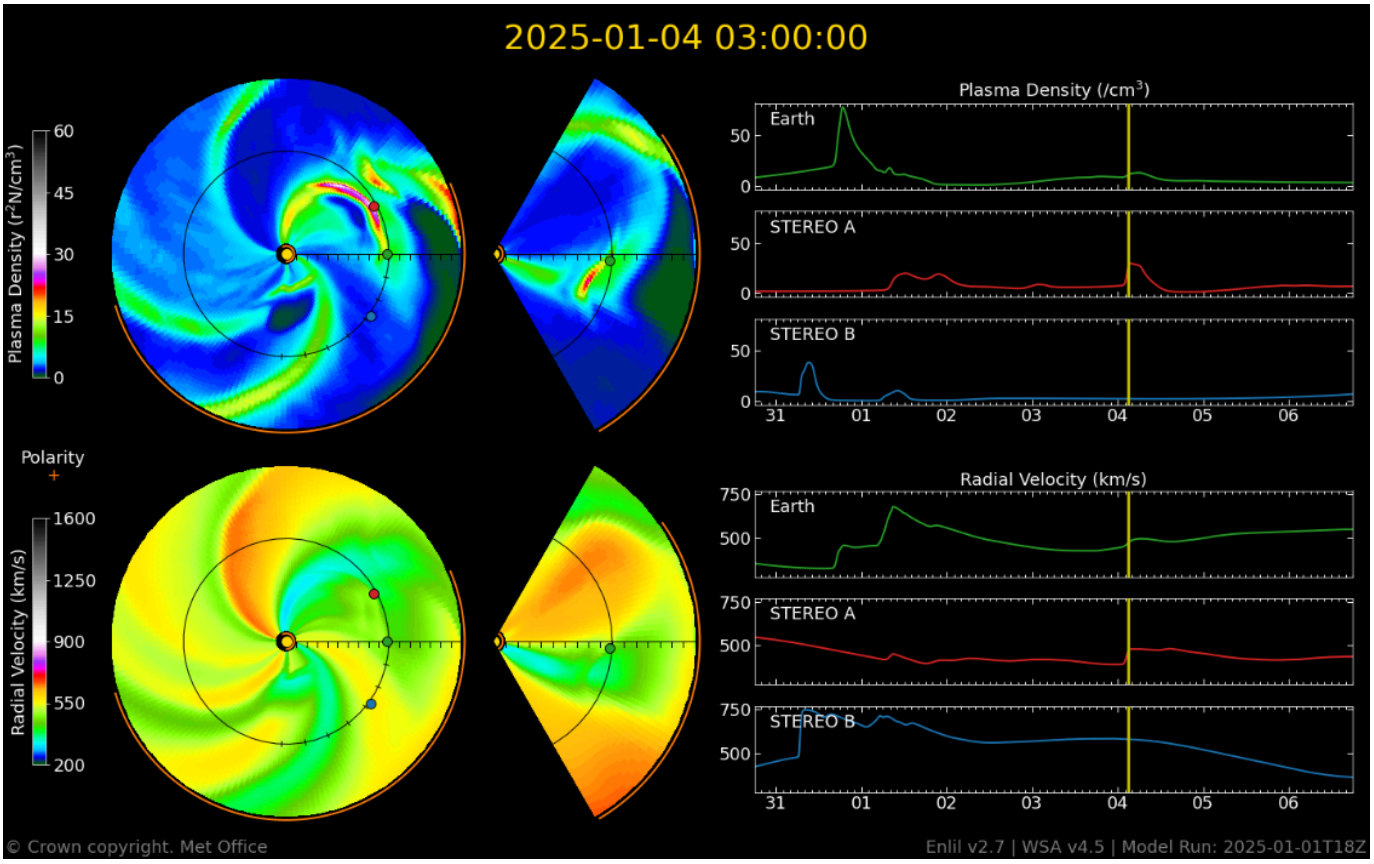
Figure 6: MOSWOC Enlil, showing weak connection and CME arrival at similar times on day 3 (04 Jan)



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Radio Blackouts - X-Ray Flares

Solar activity has persisted at Moderate with occasional M-class flares, with thirteen sunspot regions on the Earth-facing disc, and this activity is expected to continue.

The main culprit of recent activity has been AR3936, now on the northwest limb. While this does appear to be declining a significant proportion of this may be from the increased viewing angle, with some significant bright magnetic looping still evident above the spot in GOES-SUVI imagery. While solar flares from across the rest of the disc have been less frequent, there has been some growth in the last 24 hours, increasing this potential.

The most notable developing has been on the southeast disc, with AR3945 developing a number of mature penumbra containing spots, although the magnetic complexity is still difficult to assess due to its location. Also of interest in the southeast is AR3944, as while of a relatively simple bipolar structure, this has rapidly grown in the last 24 hours, and is in relative close proximity to a large north-south orientated filament to its east. A further few small unnumbered spots also emerged in this region.

The other main growth was observed in a new, yet to be numbered region on the southwest disc, to the southeast of where ex-AR3937 recently decayed to be no longer visible. AR3939 in the southeast is also of interest, as while relatively stable in size, this has been the source of the occasional flare, and has a slightly more complex magnetic structure due to small positive spots to the east and west of its main central spot. Further interest is also possible on the northeast limb, as while a spot has yet to become visible, bright magnetic looping does indicate a further active region to potentially move onto the disc.

X-Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 (M Class)	Yes	80	80	80	80
Very Active	R3-R5 (X Class)	No	15	15	10	10

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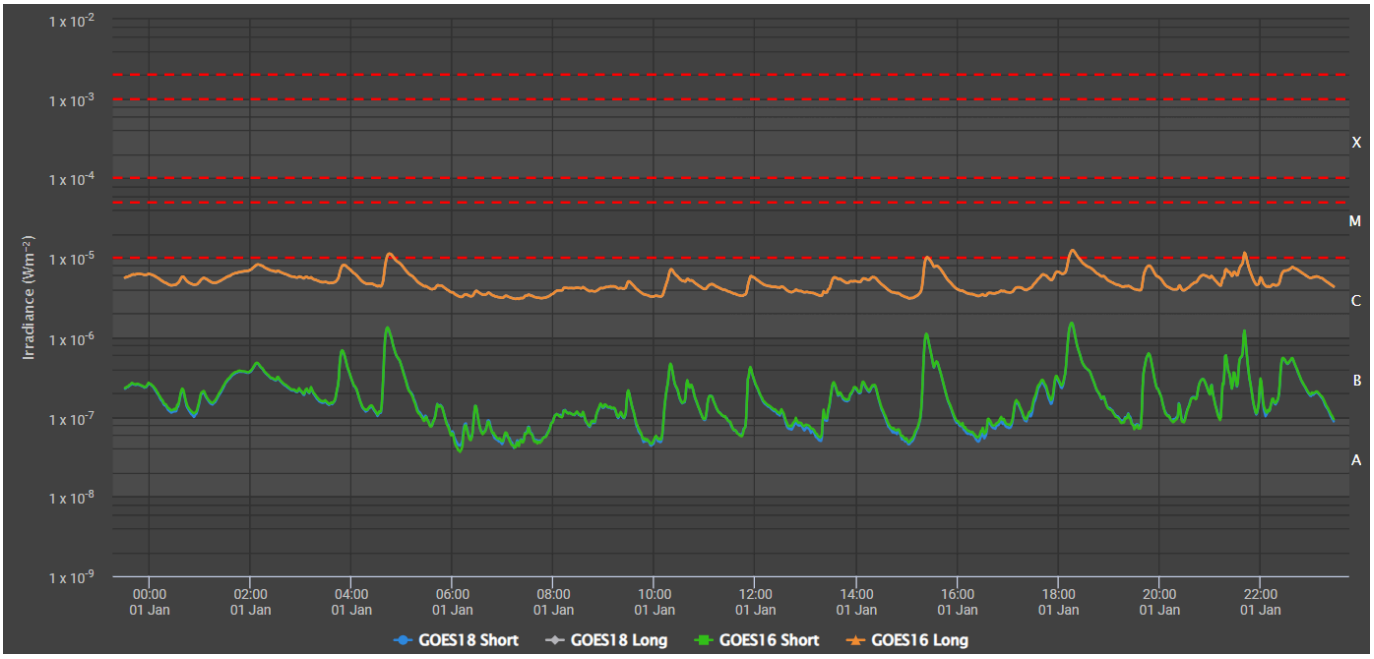
Figure 7: GOES-16/18 X-ray flux with occasional low M-class flares



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Solar Radiation Storms (High Energy Protons)

High energy proton flux as observed by GOES-18 is at background. There a number of active regions on the Earth-facing disc, including AR3936, which was the source of the most recent X-class flares, and is currently rotating over the northwest limb. These bring an ongoing chance of M-class flares, along with a chance of isolated X-class flares. Any such flares especially from the better Earth-connected western hemisphere, bring a chance of increasing the proton flux, and a slight chance of exceeding the S1 Minor Radiation Storm level.

Radiation Storms Probability (Exceedance)	Level ($cm^{-2}sr^{-1}s^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	20	20	15	15
Very Active	**≥ S3 ***	No	5	5	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and/or 50 MeV ≥ 10pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

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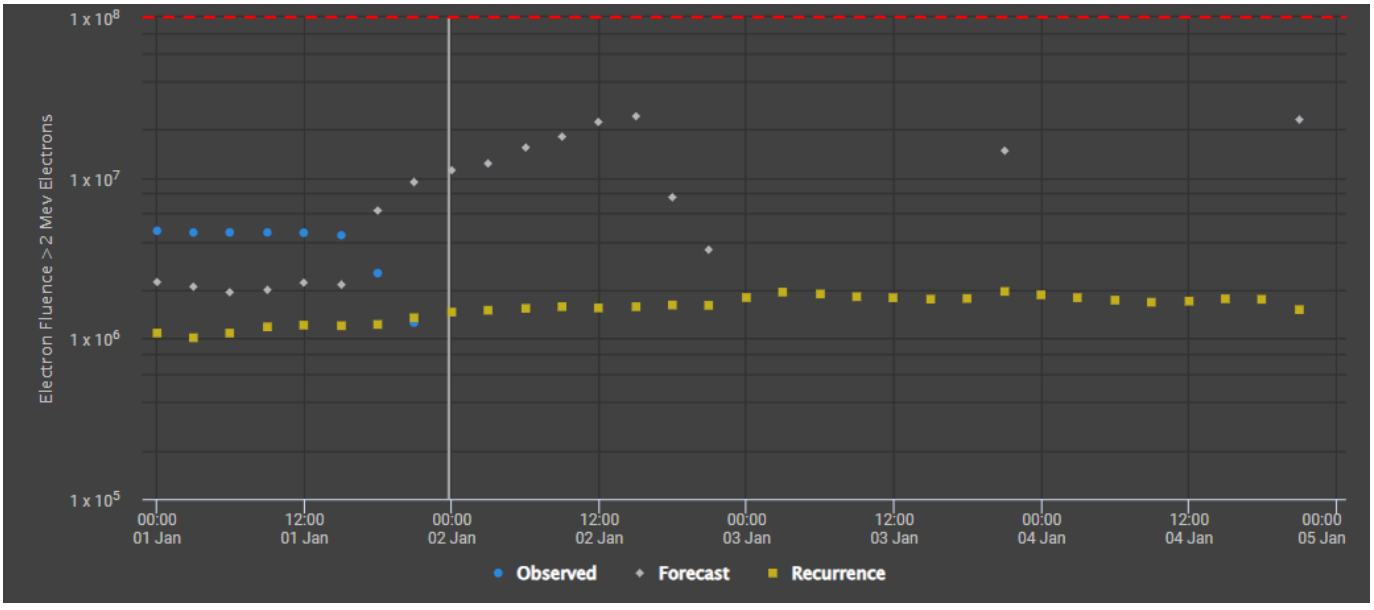
High Energy Electrons (≥ 2MeV)

High energy electron flux observed by GOES16 is currently at background. The recent CME arrival and elevated solar winds are expected to have increase flux at LEO and MEO, and as solar winds ease on day 1-2 (02-03 Jan) this is expected to expand outward towards GEO, giving the potential for a period of Moderate to High flux. The onset of any fast wind from CH05 and the potential CME arrival early on day 3 (04 Jan), then decreases confidences for the longevity of any enhanced flux, as these would likely drop values back to Background, at least for a time. However, once any initial geomagnetic activity eases, the observed flux is expected to rise again day 4 (05 Jan), bringing a chance for further spell of Moderate to High flux.

Overall the associated 24 hr fluence is most likely to persist below Active, but with a rising trend. This will bring a slight chance for periods of Active fluence, most likely days 2-3 (03-04 Jan), and then again later on day 4 (05 Jan). A rising trend is supported by MOSWOC REFM, however the current values are over-estimated, while the values later in the model forecast are potentially understimates.

GEO Electron Environment	Level ($cm^{-2}sr^{-1}$ day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ 1×10^{8}	No	1	10	10	10
Very Active	≥ 2 MeV ≥ 1×10^{9}	No	1	1	1	1

Figure 8: >2MeV Electron Fluence with MOSWOC REFM and Recurrence



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